# Breeder Age and Zinc Source in Broiler Breeder Hen Diets on Progeny Characteristics at Hatching

**B. P. Hudson,* B. D. Fairchild,*,[1] J. L. Wilson,* W. A. Dozier, III,* and R. J. Buhr†**

*Department of Poultry Science, University of Georgia, Athens, Georgia 30602-4356; and †USDA-ARS, Russell Research Center, Athens, Georgia 30605-2720*

**Primary Audience:** Physiologists, Broiler Breeder and Hatchery Managers, Researchers

## SUMMARY

**Metabolic, immune, and physical status of chicks can impact the incidence of morbidity and mortality of broilers during the first week of production. Assessments of chick quality are made primarily by subjective observations with few quantitative measurements. Given a better understanding of how broiler breeder hen age and nutrient intake may influence progeny physiology, certain actions can be taken to improve chick quality. This experiment evaluated the effects of broiler breeder age, dietary zinc source, and their interaction on the physiological characteristics of chicks at hatching. Caged broiler breeder hens were provided 1 of 3 diets from hatch through 65 wk of age. All experimental diets consisted of 160 ppm supplemental zinc from inorganic $ZnSO_4$, AvailaZn zinc-amino acid complex (ZnAA) or a mixture of ZnAA and $ZnSO_4$ (ZnAA + $ZnSO_4$, 80 ppm zinc from each).**

**Incubation length, relative organ weights, and carbohydrate status were measured in chicks from hens at 29, 41, 53, and 65 wk of age. The variation in hatch time among eggs set together was not influenced by hen age, but mean incubation length decreased from 29 to 53 wk of age and subsequently increased from 53 to 65 wk. Seasonal temperature changes may have caused confounding effects on incubation length. Chick heart glycogen declined as hens aged, and liver lactate was lowest in progeny from 65-wk-old hens. Relative yolk sac weight and relative heart weight were lowest in progeny from 29-wk-old hens. These data indicate that underdevelopment of supply organs may limit the performance of some chicks from young hens. Supplemental zinc source in breeder hen diets did not influence chick physiology at hatching.**

**Key words: broiler breeder age, zinc source, progeny, incubation length, carbohydrate metabolism**

**2004 J. Appl. Poult. Res. 13:55–64**

## DESCRIPTION OF PROBLEM

Progeny from young broiler breeder hens are typically small and may perform poorly, especially when intermingled with larger chicks. McNaughton et al. [1] reported that 1 wk mortality of broilers from 29-wk-old breeders was 2.3% greater than that of broilers from 58-wk-old breeders. Evaluating the physiological differences among chicks from broiler breeders of various ages may help identify the causes of the inadequate performances of chicks from young hens. Subsequently, these problems may be addressed to improve progeny quality throughout the reproductive period.

[1]To whom correspondence should be addressed: brianf@uga.edu.

No universally accepted method to evaluate chick quality is available. Traditionally, subjective assessments have been made by observing physical characteristics. Cervantes [2] developed a system in which chicks were scored based on physical (50%) and microbiological (50%) status. Accordingly, physical parameters evaluated were chick weight, overall appearance, apparent level of hydration, alertness, and the appearances of the eyes, navel, vent, hocks, legs, toes, and beak. Microbiological score was based upon presence and levels of *Salmonella* (in yolk sac, ileocecal junction), coliforms (in yolk sac), *Aspergillus* (in lung), and *Staphylococci* (in yolk sac). In addition to parameters observed by Cervantes [2], carbohydrate metabolism of the embryo and chick will alter hatching and subsequent performance [3, 4].

Inadequate zinc intake by breeding hens results in low hatchability and poor chick quality [5]. Supplementing broiler breeder diets with organic zinc rather than inorganic zinc has increased progeny tibia weight [6], thymus weight [7], ventricular weight [8], cellular immune response [6, 7, 9], humoral immune response [9], and livability [10]. In addition, yolk zinc concentration has been increased by supplementing hen diets with organic zinc rather than inorganic zinc [11]. Based on the stimulatory effect that zinc has on glucose utilization in humans and laboratory animals [12], supplemental zinc source in breeder diets may alter carbohydrate metabolism in the chick.

The embryo's oxygen demand increases with age and will eventually exceed the oxygen diffusion rate through the eggshell near the end of embryonic development. This disparity will result in embryonic hypoxia [13] and requires the embryo to use anaerobic metabolism (gluconeogenesis and glycolysis) for energy production [14]. Glycogen is formed during embryonic development by glycosidic linkage of glucose subunits subsequent to gluconeogenesis [15], and it is utilized as an energy source during the hypoxic conditions of hatching [3]. When blood glucose concentrations decline, the liver plays a critical role of converting lactate into glucose-6-phosphate and supplies energy to demand organs [16]. Cardiac and skeletal muscles are described as demand organs, because they lack the ability to recycle lactate [14]. Ultimately, low glucose status or abnormal glucose regulation may adversely affect the hatching process or subsequent chick performance.

Although carbohydrate metabolism has been measured previously with poults, similar data regarding physiological development of chicks are limited. The purpose of this experiment was to determine the effects of broiler breeder hen age and dietary zinc source in broiler breeder hen diets on chick characteristics at hatch.

## MATERIALS AND METHODS

### *Experimental Diets and Bird Management*

Chicks were hatched from slow-feathering Cobb 500 broiler breeder hens at 4 different ages (29, 41, 53, and 65 wk). Treatments consisted of the 4 hen ages and 3 zinc sources supplemented in the hen diets. The hens were given 1 of 3 diets from 0 through 65 wk of age (Table 1). Experimental diets consisted of 160 ppm supplemental Zn from $ZnSO_4$, AvailaZn zinc-amino acid complex (ZnAA), or a combination of $ZnSO_4$ and AvailaZn (ZnSO4+ZnAA, 80 ppm zinc from each). The supplemental zinc concentration used in this experiment was similar to that used with inorganic zinc supplements in the commercial poultry industry. Inductively coupled plasma analyses were conducted in duplicate to determine the zinc content of the basal and experimental diets [17]. Determined or analyzed concentrations were comparable to calculated concentrations throughout the experiment (basal: average calculated value = 31 ppm; analyzed value = 39 ± 8 ppm; supplemented: calculated value = 172 ppm; analyzed value = 185 ± 36 ppm; n = 18). Differences between calculated and analyzed concentrations were likely due to an underestimation of zinc in the corn and soybean meal.

Pullets were raised on pine shavings in 3 environmentally controlled rooms (1 room per dietary treatment) with 8-h day lengths. Dietary treatment and environment were confounded during the rearing period, but the integrity of the experiment was not compromised due to similar environmental conditions maintained in all rooms. Birds were randomly assigned to cages in a laying facility at 20 wk of age, and 16 h light/d was provided. There were 8 replicate groups of 24 caged hens in each dietary treat-

TABLE 1. Ingredient composition and calculated nutrient analysis of the basal diets provided to broiler breeder pullets and hens[A]

| Ingredients, % "as is" | Starter[B] | Developer[C] | Breeder 1[D] | Breeder 2[E] |
|---|---|---|---|---|
| Corn | 62.95 | 58.81 | 68.15 | 68.54 |
| Soybean meal (48% CP) | 22.24 | 16.90 | 20.71 | 18.68 |
| Poultry oil | — | — | 1.00 | 1.67 |
| Wheat middlings | 10.53 | 20.10 | — | — |
| Limestone | 1.15 | 1.16 | 7.41 | 8.37 |
| Dicalcium phosphate | 1.75 | 1.76 | 1.46 | 1.50 |
| Sodium chloride | 0.54 | 0.58 | 0.54 | 0.54 |
| L-Lysine HCl | 0.10 | — | — | — |
| DL-Methionine | 0.15 | 0.06 | 0.14 | 0.11 |
| Trace mineral premix[F] | 0.08 | 0.08 | 0.08 | 0.08 |
| Vitamin premix[G] | 0.50 | 0.50 | 0.50 | 0.50 |
| Copper sulfate | 0.01 | 0.05 | 0.01 | 0.01 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 |
| Calculated analyses | | | | |
| Crude protein (%) | 18.00 | 15.50 | 15.90 | 15.00 |
| Metabolizable energy (kcal/kg) | 2,865 | 2,819 | 2,900 | 2,900 |
| Calcium (%) | 0.91 | 0.90 | 3.22 | 3.60 |
| Available phosphorus (%) | 0.45 | 0.42 | 0.38 | 0.36 |
| Lysine (%) | 1.00 | 0.78 | 0.83 | 0.82 |
| Methionine (%) | 0.43 | 0.32 | 0.40 | 0.33 |
| TSAA (%) | 0.73 | 0.60 | 0.66 | 0.66 |
| Sodium (%) | 0.21 | 0.22 | 0.21 | 0.20 |
| Copper (ppm) | 16 | 16 | 16 | 16 |
| Zinc (ppm) | 35 | 41 | 23 | 23 |

[A]Experimental diets were prepared by adding 160 ppm zinc from $ZnSO_4$, AvailaZn zinc-amino acid complex (ZnAA) or a mixture of ZnAA and $ZnSO_4$ (80 ppm zinc from each) to the basal diet. Basal diets provided approximately 40 ppm zinc based upon actual analyses.
[B]Diet was provided from 0 to 19 d of age to all females.
[C]Diet was provided from 20 d to 22 wk of age to all females.
[D]Diet was provided from 23 to 47 wk of age to all females.
[E]Diet was provided from 48 to 66 wk of age to all females.
[F]Trace mineral premix provided the following in milligrams per kilogram of diet: selenium, 0.3; manganese, 121; iron, 75; iodine, 0.8.
[G]Vitamin premix provided the following per kilogram of diet: vitamin A, 11,000 IU; vitamin $D_3$, 2,200 IU; vitamin E, 22 IU; vitamin K, 2.2 mg; vitamin $B_{12}$, 0.2 mg; thiamine, 4.4 mg; riboflavin, 8.8 mg; vitamin B6, 4.4 mg; niacin, 88 mg; pantothenic acid, 22 mg; folic acid, 1.1 mg; biotin, 2.2 mg; choline, 380 mg.

ment with 2 hens per cage for a total of 192 hens per dietary treatment. After hens were caged, 1 replicate group per treatment was labeled and weighed weekly through 40 wk and biweekly thereafter to determine feed allotments. Management was provided according to primary breeder recommendations, and feed allotments adjusted to achieve target BW suggested by a broiler integrator.

### *Incubation Procedures*

Hens were artificially inseminated with 50 $\mu$L of neat semen on 2 occasions (5 d prior to egg collection and 1 d after egg collection began) for each of the 4 hen age periods. Eggs that were laid at 29, 41, 53, and 65 wk of breeder age were incubated and hatched in incubators and hatchers [18]. An average of 76 hatching eggs were set from each replicate group of hens at each of the 4 hen ages. Eggs from 29, 41, 53, and 65 wk of breeder age were set during January, April, June, and September, respectively. Incubation temperature settings from 0 to 18 and 19 to 21 d of incubation were 37.8 and 37.2°C, respectively. Relative humidity settings at 0 to 19 and 20 to 21 d of incubation were 53 and 70%, respectively. Hatching eggs from each replicate group of 24 hens represented an experimental unit. Eggs were randomly set and transferred by replicate group into the incubator and hatcher, respectively. Each treatment was represented with eggs from 1 replicate group within each of

TABLE 2. Influences of broiler breeder hen age and dietary zinc source on incubation length[A]

| Contrast | Mean incubation length (h) | Distribution of incubation length (CV, %) |
|---|---|---|
| Age (wk) | *** | NS[B] |
| 29 | 489.3[a] | 1.44 |
| 41 | 487.5[b] | 1.33 |
| 53 | 484.4[c] | 1.46 |
| 65 | 486.8[b] | 1.45 |
| SEM | 0.23 | 0.063 |
| Diet[C] | NS | NS |
| $ZnSO_4$ | 487.1 | 1.40 |
| ZnAA 487.2 | 1.49 | |
| ZnAA+$ZnSO_4$ | 486.6 | 1.37 |
| SEM | 0.38 | 0.046 |

[a–c]Means with different superscripts within a column signify significant differences ($P \leq 0.05$).
[A]Values are least-squares means involving 24 hen groups, each with 24 hens at housing. Hatched chicks were counted and removed on 4-h intervals from 468 through 528 h.
[B]$P > 0.05$.
[C]Broiler breeder hens were given 1 of 3 diets. Diets consisted of 160 ppm supplemental Zn from $ZnSO_4$, AvailaZn zinc-amino acid complex (ZnAA), or a mixture of ZnAA and $ZnSO_4$ (ZnAA + $ZnSO_4$, 80 ppm zinc from each).
***$P \leq 0.001$.

the 8 designated areas within the incubator and hatcher. Eggs were turned hourly from 0 to 18 d of incubation, and they were transferred to hatchers after 18 d of incubation. Chicks that had dry down except for dampness on the back of the neck were removed and counted on 4-h intervals from 468 through 528 h of incubation. Mean incubation length and distribution of incubation length were calculated. All hatching eggs laid on a single day were weighed on 4-wk intervals from 26 to 66 wk of age.

### *Physiological Development of Chicks*

To evaluate physiological development of chicks, 2 chicks from each replicate group of hens were randomly removed from the hatcher at 492 h (20.5 d) of incubation. Two chicks from each replicate were assessed at each age so that sampling could be completed in a timely manner, and hatching or holding times did not influence the results. After being weighed, chicks were decapitated, and trunk blood samples were collected in tubes containing 72 USP units of sodium heparin. Blood plasma was stored at −4°C until analyzed for glucose concentration [19]. Yolk sac, heart, liver, and pipping muscle

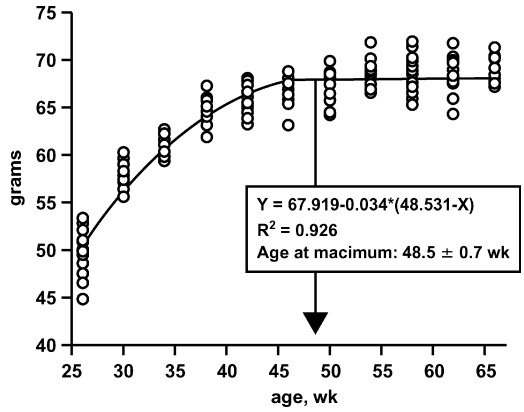


FIGURE 1. Influence of broiler breeder hen age on egg weight.

were excised from each chick and weighed to the nearest 0.001 g. The portion of the small intestine between the bile duct entry and the cecal branch was removed. The intestinal segment was then separated into jejunum and ileum sections at Meckel's diverticulum [20] and blotted dry. The unstretched length and weight of each segment was then measured. Yolk sac weights are presented as a percentage of chick weight, and all other organ (liver, heart, pipping muscle, jejunum, and ileum) weights are presented as percentages of yolk sac-free chick weight.

Left and right liver lobes were separated at the narrowest junction. Right liver lobes were held at −4°C until analyzed for zinc concentration on a dry matter basis by inductively coupled plasma analyses [17]. Left liver lobes and hearts were immediately placed in a cold 7% perchloric acid solution [21]. The homogenates were centrifuged at 700 g for 10 min at 4°C. Glycogen and lactate concentrations were determined in the supernatant fraction. Glycogen concentrations in heart and liver homogenates were assayed by the technique of Dreiling et al. [21]. Lactate concentration was measured in liver and heart homogenates by techniques described by Donaldson and Christensen [22]. Data were subjected to ANOVA for statistical analyses [23].

## RESULTS AND DISCUSSION

### *Incubation Length*

The effects of hen age will be primarily discussed in this article because dietary zinc source

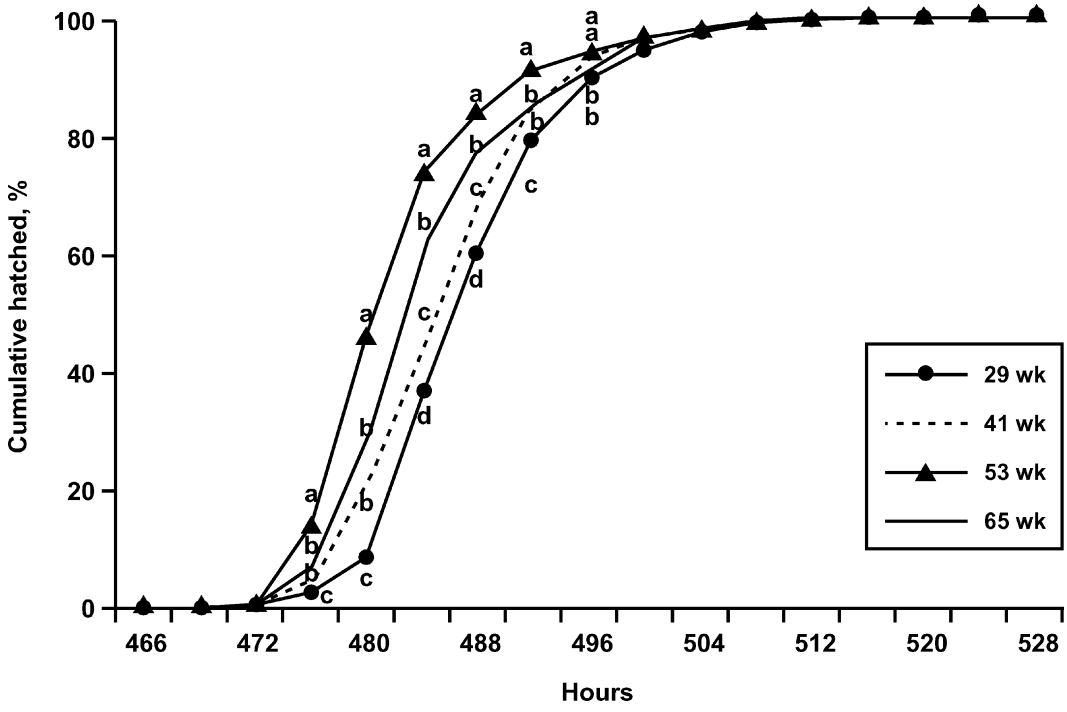


FIGURE 2. Influence of broiler breeder hen age on incubation time. Superscripts signify a significant difference ($P < 0.05$) at a particular hour.

had limited effects on the chick characteristics evaluated. Incubation period generally lengthens as hen age progresses and egg size increases [25, 26, 27]. In this experiment, egg weight increased rapidly until approximately 48 wk of age (Figure 1). However, the mean incubation length declined consistently from 29 to 53 wk of age and increased from 53 to 65 wk of age (Table 2).

Results from this study indicate that variation in hatch time within each age group was not significantly different (Table 2). These data agree with Reis et al. [28], who reported that hen age (33 vs. 49 wk) did not alter distribution of incubation length. Although hen age did not affect variation of hatching time, age influenced the time that hatching initiated (Figure 2). Hatching was delayed in progeny from 29-wk-old hens. Only 10.0% of the total chicks from 29-wk-old hens had hatched at 480 h of incubation, but 24.6, 46.6, and 28.3% of chicks hatched from 41-, 53-, and 65-wk-old hens, respectively ($P < 0.05$). After 492 h of incubation, 79.9, 86.7, 91.7, and 85.2% of total chicks hatched from 29-, 41-, 53-, and 65-wk-old breeders, respectively ($P < 0.05$).

Incubation length may be prolonged in eggs from young hens for several reasons. Embryos from young hens are less advanced at oviposition and have lower metabolic rates during the first 2 d of incubation [29]. Relatively little blastoderm development at oviposition may be due to shorter durations of eggs in the oviduct [30] in combination with superior albumen quality, which may allow less gas exchange and oxygen availability in the oviduct [31]. In addition to the previously mentioned reasons, relatively low seasonal temperatures may have been responsible for prolonged incubation length of eggs from 29-wk-old hens. Increasing ambient temperatures associated with the changing seasons (January to September) were likely responsible for decreasing incubation lengths as hens aged. High temperatures in the breeding facility and hatchery during the late spring and early summer might have accelerated embryonic development.

### *Body and Organ Weight*

McNaughton et al. [1] reported that average BW of chicks from 29-wk-old broiler breeders

TABLE 3. Influences of broiler breeder hen age and dietary zinc source on chick weight, organ weights, and hepatic zinc concentration[A]

| Contrast | Chick weight (g) | Liver weight (%)[B] | Heart weight (%)[B] | Yolk sac weight (%)[C] | Pipping muscle weight (%)[B] | Liver zinc[D](ppm) |
|---|---|---|---|---|---|---|
| Age (wk) | *** | *** | *** | *** | NS[F] | NS |
| 29 | 37.9[c] | 2.41[ab] | 0.71[b] | 12.5[b] | 1.75 | 63.0 |
| 41 | 46.4[b] | 2.21[c] | 0.82[ab] | 16.2[a] | 1.59 | 62.4 |
| 53 | 47.1[ab] | 2.46[a] | 0.86[a] | 15.7[a] | 1.49 | 62.2 |
| 65 | 48.6[a] | 2.29[bc] | 0.80[ab] | 16.6[a] | 1.62 | 63.6 |
| SEM | 0.66 | 0.048 | 0.019 | 0.48 | 0.083 | 0.45 |
| Diet[E] | NS | NS | NS | NS | NS | NS |
| $ZnSO_4$ | 38.2 | 2.31 | 0.81 | 15.5 | 1.72 | 63.0 |
| ZnAA 37.5 | 2.42 | 0.81 | 15.4 | 1.56 | 62.8 | |
| ZnAA+$ZnSO_4$ | 38.5 | 2.30 | 0.78 | 15.0 | 1.56 | 62.6 |
| SEM | 0.47 | 0.041 | 0.008 | 0.40 | 0.092 | 0.54 |

[a–c]Means with different superscripts within a column signify significant differences ($P \leq 0.05$).
[A]Values are least-squares means involving 2 chicks from each of 24 hen groups. Chicks were sampled at 4 different breeder ages.
[B]Percentage of yolk-free chick weight.
[C]Percentage of chick weight.
[D]Assayed by inductively coupled plasma analysis. Values are presented on a dry matter basis.
[E]Broiler breeder hens were given 1 of 3 diets. Diets consisted of 160 ppm supplemental Zn from $ZnSO_4$, AvailaZn zinc-amino acid complex (ZnAA), or a mixture of ZnAA and $ZnSO_4$ (ZnAA + $ZnSO_4$, 80 ppm zinc from each).
[F]$P > 0.05$.
*$P \leq 0.05$.
**$P \leq 0.01$.
***$P \leq 0.001$.

was approximately 6 g less ($P < 0.05$) than that of chicks from 58-wk-old breeders. In this study, BW of chicks from 41-wk-old hens was 8.5 g greater than BW of progeny from the same hens at 29 wk of age (Table 3). The weights of chicks from 65-wk-old hens were also significantly greater than chicks from 41-wk-old hens. Age effects on yolk-free chick weight followed the same trend.

Organ weights from chicks at hatching were influenced by age of the breeders (Table 3). Relative liver weights of progeny were lowest at 41 wk, highest at 53 wk, and intermediate at 29 and 65 wk of age. Relative heart weights in progeny were lowest when hens were 29 wk of age, indicating that chicks from young hens may have a limited ability to supply nutrients to demand organs. Fairchild and Christensen [32] suggested that poults with relatively low heart or liver weights might be at a disadvantage because of underdevelopment of these supply organs. Dietary zinc source did not influence progeny heart weights in this experiment or in other research [33], but supplementing broiler breeder diets with zinc and manganese has increased ventricular weight of progeny [8]. Virden et al. [8] suggested that higher zinc and manganese supplementation in breeder diets could enhance cardiac output and reduce ascites in broilers.

Relative yolk sac weight at 29 wk of age was significantly lower than at subsequent hen ages (Table 3). These data agree with previous reports of increasing relative yolk sac weights as broiler breeder hens [34, 35] and turkey hens [36] age. However, Latour et al. [37] reported that relative yolk sac weights of chicks from 51-wk-old breeders were smallest when compared with chicks from the breeders at 36 and 64 wk of age.

Chick jejunum weight, length, and density were greatest when hens were 53 wk of age (Table 4). Since small intestine length [38] and luminal surface area [39] have been directly related to rapid growth of poultry, intestinal data may imply that growth of chicks from 53-wk-old hens may be enhanced. It is not clear why jejunum development was greatest in progeny of 53-wk-old hens. The only noticeable differences at 53 wk were the warmer seasonal temperatures and an earlier mean hatch time of 2

TABLE 4. Influences of broiler breeder hen age and dietary zinc source on intestinal development of progeny[A]

| | Segment weight[B] | | Segment length (cm) | | Segment density[C] | |
|---|---|---|---|---|---|---|
| Contrast | Jejunum | Ileum | Jejunum | Ileum | Jejunum | Ileum |
| Age (wk) | *** | *** | *** | NS[E] | *** | NS |
| 29 | 0.99[a] | 0.96[a] | 14.0[b] | 12.9 | 23.7[b] | 24.8 |
| 41 | 0.85[b] | 0.80[b] | 13.5[b] | 12.7 | 24.6[b] | 24.4 |
| 53 | 1.06[a] | 0.84[b] | 15.1[a] | 12.8 | 27.9[a] | 26.0 |
| 65 | 0.81[b] | 0.74[b] | 13.4[b] | 12.3 | 24.2[b] | 24.0 |
| SEM | 0.029 | 0.035 | 0.29 | 0.25 | 0.67 | 0.83 |
| Diet[D] | NS | NS | NS | NS | NS | NS |
| $ZnSO_4$ | 0.91 | 0.80 | 14.2 | 12.6 | 24.3 | 24.2 |
| ZnAA | 0.95 | 0.88 | 13.9 | 12.5 | 25.7 | 25.9 |
| ZnAA+$ZnSO_4$ 0.92 | 0.82 | 13.9 | 12.9 | 25.3 | 24.4 | |
| SEM | 0.034 | 0.032 | 0.26 | 0.20 | 0.57 | 0.49 |

[a–c]Means with different superscripts within a column signify significant differences ($P \leq 0.05$).
[A]Values are least-squares means involving 2 chicks from each of 24 hen groups. Chicks were sampled at 4 different breeder ages.
[B]Percentage of yolk-free chick weight.
[C]Calculated as weight (mg)/length (cm).
[D]Broiler breeder hens were given 1 of 3 diets. Diets consisted of 160 ppm supplemental Zn from $ZnSO_4$, AvailaZn zinc-amino acid complex (ZnAA), or a mixture of ZnAA and $ZnSO_4$ (ZnAA + $ZnSO_4$, 80 ppm zinc from each).
[E]$P > 0.05$.
*$P \leq 0.05$.
**$P \leq 0.01$.
***$P \leq 0.001$.

hr. Hot conditions in the breeder facility and hatchery may have altered embryonic development prior to artificial incubation.

Progeny from 53-wk-old hens had increased ileum lengths when hens consumed $ZnSO_4$ (14.0 mm) rather than ZnAA (12.3 mm) or ZnAA+ZnSO4 (12.2 mm). This may suggest that nutrient absorption would be improved in these chicks. However, these differences due to dietary zinc source may have been influenced more by high seasonal temperatures at 53 wk rather than hen age. Pharmacological levels of dietary zinc have prevented duodenal regression in molted laying hens [40] and stimulated enterocyte development of weanling pigs [41], but no prior research has reported a relationship between dietary zinc in hen diets and ileum length in progeny.

### *Carbohydrate Metabolism*

Researchers have reported that plasma glucose is replenished as hepatic glycogen stores are depleted in poults exposed to stressors or held for extended periods [42, 43, 44]. Therefore, high glycogen concentrations in chicks are desirable as an energy reserve during servicing and transport to growout facilities. Applegate and Lilburn [45] reported that poults from young hens had higher fasting plasma glucose concentrations than those from older hens. In another experiment, ducklings from younger hens maintained elevated blood glucose concentrations (33 wk = 374 mg/dL; 48 wk = 273 mg/dL) at 60 min after a glucose injection compared with ducklings from younger hens [46]. The authors suggested that metabolic homeostasis might be poorly controlled in progeny from young hens.

Carbohydrate metabolism was influenced by hen age (Table 5). Plasma glucose concentrations of progeny were lowest when hens were 53 wk of age. Conversely, Latour et al. [34] reported that chicks from 26-wk-old hens had lower plasma glucose concentrations than chicks from 36-or 48-wk-old hens. Reasons for inconsistencies between these 2 research reports are not clear. Although, it is possible that rapid development of embryos from 53-wk old hens increased glucose catabolism during incubation, resulting in lower plasma glucose concentrations at hatch. If low glucose status occurred with progeny from 53-wk-old hens, it would be expected that hepatic glycogen would be expended or glycolytic activity would be depressed in the liver. However, similar concentrations of hepatic

TABLE 5. Influences of broiler breeder hen age and dietary zinc source on glucose metabolism in progeny[A]

| Contrast | Plasma glucose (mg/dL) | Liver glycogen (mg/g) | Heart glycogen (mg/g) | Liver lactate (mg/g) | Heart lactate (mg/g) |
|---|---|---|---|---|---|
| Age (wk) | *** | NS[C] | *** | *** | NS |
| 29 | 395[a] | 7.7 | 8.7[a] | 0.62[a] | 1.54 |
| 41 | 383[a] | 9.0 | 7.0[b] | 0.58[a] | 1.51 |
| 53 | 339[b] | 9.0 | 5.5[c] | 0.46[b] | 1.51 |
| 65 | 369[a] | 8.2 | 4.3[d] | 0.37[c] | 1.46 |
| SEM | 9.1 | 0.62 | 0.29 | 0.019 | 0.057 |
| Diet[B] | NS | NS | NS | NS | NS |
| $ZnSO_4$ | 381 | 8.5 | 6.2 | 0.51 | 1.51 |
| ZnAA | 375 | 8.6 | 6.8 | 0.50 | 1.53 |
| ZnAA+$ZnSO_4$ | 358 | 8.3 | 6.2 | 0.51 | 1.50 |
| SEM | 11.1 | 0.77 | 0.21 | 0.017 | 0.023 |

[a–c]Means with different superscripts within a column signify significant differences ($P \leq 0.05$).
[A]Values are least-squares means involving 2 chicks from each of 24 hen groups. Chicks were samples at 4 different breeder ages.
[B]Broiler breeder hens were given 1 of 3 diets. Diets consisted of 160 ppm supplemental Zn from $ZnSO_4$, AvailaZn zinc-amino acid complex (ZnAA), or a mixture of ZnAA and $ZnSO_4$ (ZnAA + $ZnSO_4$, 80 ppm zinc from each).
[C]$P > 0.05$.
*$P \leq 0.05$.
**$P \leq 0.01$.
***$P \leq 0.001$.

glycogen in chicks from each of the hen age groups suggest that this did not occur.

Breeder age had no influence on glycogen concentration in chick livers (Table 5). In contrast, Christensen et al. [47] reported that young turkey hens produced embryos with greater amounts of glycogen than did older hens, perhaps due to a limited ability of these chicks to catabolize glycogen. Glycogen concentration in the heart decreased consistently as the parents aged. This may indicate that more glycogen is mobilized from the liver to peripheral organs in embryos from young hens. Hen age did not alter lactate concentration in the heart (Table 5). Liver lactate concentration was lowest in progeny from 65-wk-old hens, suggesting that more lactate was recycled to glucose.

These data indicate that incubation length generally shortened as hens aged, but rising environmental temperatures may have increased the embryonic development rate as hens approached 53 wk of age. Less developed hearts and yolk sacs observed in chicks from young hens may limit their performance. Breeder hen age influenced progeny plasma glucose, heart glycogen, and liver lactate concentrations, suggesting a difference in initial carbohydrate availability or carbohydrate metabolism. Dietary zinc in broiler breeder hen diets had little impact on variables used to assess physiological status of chicks in this experiment. Additional work is needed to determine how modifications to breeder and hatchery management can improve chick physiology at hatching to optimize subsequent performance.

## CONCLUSIONS AND APPLICATIONS

1. Chicks from 29-wk-old hens had lower relative yolk sac weight and relative heart weight. These may be critical factors limiting the performance of chicks from young broiler breeder flocks.
2. Carbohydrate metabolism of progeny was influenced by broiler breeder hen age. Further research is needed to determine the relationship between carbohydrate status of chicks and subsequent performance.
3. Zinc source in hen diets did not influence the variables used in this study to assess the physiological development of their progeny.

## REFERENCES AND NOTES


1. McNaughton, J. L., J. W. Deaton, and R. N. Reece. 1978. Effect of age of parents and hatching egg weight on broiler chick mortality. Poult. Sci. 57:38–44.

2. Cervantes, H. 1993. A new formula for chick quality. Proc. Hatchery-Breeder Flock Management Clinic, Birmingham, AL.

3. Freeman, B. M. 1965. The importance of glycogen at the termination of the embryonic existence of *Gallus domesticus.* Comp. Biochem. Physiol. 28:1169–1176.

4. Uni, Z., Y. Noy, and D. Sklan. 1995. Posthatch changes in morphology and function of the small intestines in heavy- and light-strain chicks. Poult. Sci. 74:1622–1629.

5. Blamberg, D. L., U. B. Blackwood, W. C. Supplee, and G. F. Combs. 1960. Effect of zinc deficiency in hens on hatchability and embryonic development. Proc. Soc. Exp. Biol. Med. 104:217–220.

6. Kidd, M. T., N .B. Anthony, and S. R. Lee. 1992. Progeny performance when dams and chicks are fed supplemental zinc. Poult. Sci. 71:1201–1206.

7. Virden, W. S., J. B. Yeatman, S. J. Barber, K. O. Willeford, T. L. Ward, T. M. Fakler, and M. T. Kidd. 2002. Responses of chicks from broiler breeders fed supplemental zinc and manganese: Cellular immunity. Poult. Sci. 81(Suppl. 1):119. (Abstr.)

8. Virden, W. S., T. L. Ward, R. F. Wideman, Jr., and M. T. Kidd. 2002. Cardio-pulmonary evaluations of cold-challenged chicks from parents fed supplemental zinc and manganese amino acid complexes. Poult. Sci. 81(Suppl. 1):38. (Abstr.)

9. Kidd, M. T., N. B. Anthony, L. A. Newberry, and S. R. Lee. 1993. Effect of supplemental zinc in either a corn-soybean or a milo and corn-soybean meal diet on the performance of young broiler breeders and their progeny. Poult. Sci. 72:1492–1499.

10. Virden, W. S., J. B. Yeatman, S. J. Barber, C. D. Zumwalt, T. L. Ward, A. B. Johnson, and M. T. Kidd. 2002. Responses of chicks from broiler breeders fed supplemental zinc and manganese: Live performance and processing. Poult. Sci. 81(Suppl. 1):119. (Abstr.)

11. Guo, Y. M., R. Yang, J. Yuan, T. L. Ward, and T. M. Fakler. 2002. Effect of Availa®Zn and $ZnSO_4$ on laying hen performance and egg quality. Poult. Sci. 81(Suppl. 1):40. (Abstr.)

12. Braneo-Neto, J., V. Stefan, B. B. Mendonca, W. Bloise, A. V. Castro. 1995. The essential role of zinc in growth. Nutr. Res. 15:335–358.

13. Rahn, H. 1981. Gas exchange in avian eggs with special reference to turkey eggs. Poult. Sci. 60:1971–1980.

14. Christensen, V. L., W. E. Donaldson, and K. E. Nestor. 1999. Effect of supplemental oxygen on blood plasma organic acids within embryos from selected lines of turkeys. Poult. Sci. 78:1601–1605.

15. Mayes, P. A. 1993. Metabolism of glycogen. Pages 181-189 in Harper's Biochemistry. 23rd ed. Murry, R. K., D. K. Granner, P. A. Mayes, and V. W. Rodwell, ed. Appleton and Lange, Norwalk, CT.

16. Watford, M., U. Hod, Y. Chao, M. Utter, and R. W. Hanson. 1981. The unique role of the kidney in gluconeogenesis in the chicken. J. Biol. Chem. 256:10023–10027.

17. Maxfield, R., and B. Mindak. 1985. EPA Method Study 27, Method 200.7. EPA-600/S4-85/05. Natl. Tech. Information Serv., Springfield, VA.

18. Natureform Hatchery Systems, Jacksonville, FL 32202.

19. Trinder, P. 1969. Determination of blood glucose using an oxidase-peroxidase system with a non-carcinogenic chromagen. J. Clin. Pathol. 22:158–161.

20. Denbow, D. M. 2000. Gastrointestinal anatomy and physiology. Pages 299–325 in Sturkie's Avian Physiology. G. C. Whittow, ed. Springer-Verlag, New York.

21. Dreiling, D. E., D. E. Brown, L. Casale, and L. Kelly. 1987. Muscle glycogen: Comparison of iodine binding and enzyme digestion assays and application to meat samples. Meat Sci. 20:167–177.

22. Donaldson, W. E., and V. L. Christensen. 1994. Dietary carbohydrate effects on some plasma organic acids and aspects of glucose metabolism in turkey poults. Comp. Biochem. Physiol. 109A:423–430.

23. Dietary treatments were arranged in a completely randomized block design, with block corresponding to cage location. Statistical analysis was conducted using the General Linear Models procedure of SAS software [24] for a split-plot design with breeder diet as the whole-plot factor and hen age as the subplot factor. Replicate hen group (2 chicks at each age) served as the experimental unit. This allowed for testing of age, dietary zinc source, and age x dietary zinc source effects. Data are presented as main contrasts due to the infrequency of significant interactions; however, information was expanded when significant interactions were observed. Statistical significance was considered at $P \leq 0.05$. To determine the breeder age at which an egg weight plateau occurred, the NLIN procedure of SAS software was used. All percentage data were subjected to arc sine transformation prior to analysis. While conclusions were drawn from the transformed data, only untransformed data are presented for relevance.

24. SAS Institute. 1996. Statistical Analytical System User's Guide. Version 6.12 Edition. SAS Institute Inc., Cary, NC.

25. Byerly, T. C. 1933. Some factors affecting the length of the incubation period. Proc. 5th World's Poult. Congr. 2:373–379.

26. Olsen, M. W. 1942. The effect of age and weight of turkey eggs on the length of the incubation period. Poult. Sci. 21:532–535.

27. Williams, C., G. F. Godfrey, and R. B. Thompson. 1951. The effect of rapidity of hatching on growth, egg production, mortality and sex ratios in the domestic fowl. Poult. Sci. 30:599–606.

28. Reis, L. H., L. T. Gama, and M. C. Soares. 1997. Effects of short storage conditions and broiler breeder age on hatchability, hatching time, and chick weights. Poult. Sci. 76:1459–1466.

29. Mather, C. M., and K. F. Laughlin. 1979. Storage of hatched eggs: The interaction between parental age and early embryonic development. Br. Poult. Sci. 20:595–604.

30. Bernier, P. E., L. W. Taylor, and C. A. Gunns. 1951. The relative effects of inbreeding and outbreeding on reproduction in the domestic fowl. Hilgardia 20:529–628.

31. Brake, J., T .J. Walsh, C. E. Benton, J. N. Petitte, R. Meijerhof, and G. Penalva. 1997. Egg handling and storage. Poult. Sci. 76:144–151.

32. Fairchild, B. D., and V. L. Christensen. 2000. Photostimulation of turkey eggs accelerates hatching times without affecting hatchability, liver or heart growth, or glycogen content. Poult. Sci. 79:1627–1631.

33. Kidd, M. T., M. A. Qureshi, P. R. Ferket, and L. N. Thomas. 2000. Turkey hen zinc source affects progeny immunity and disease resistance. J. Appl. Poult. Res. 9:414–423.

34. Latour, M. A., E. D. Peebles, C. R. Boyle, S. M. Doyle, T. Pansky, and J. D. Brake. 1996. Effects of breeder age and dietary fat on embryonic and neonatal broiler serum lipids and glucose. Poult. Sci. 75:695–701.

35. Peebles, E. D., C. D. Zumwalt, S. M. Doyle, P. D. Gerard, M. A. Latour, C. R. Boyle, and T. W. Smith. 2000. Effects of breeder age and dietary fat source and level on broiler hatching egg characteristics. Poult. Sci. 79:698–704.

36. Applegate, T. J., and M. S. Lilburn. 1996. Independent effects of hen age and egg size on incubation and poult characteristics in commercial turkeys. Poult. Sci. 75:1210–1216.

37. Latour, M. A., E. D. Peebles, S. M. Doyle, T. Pansky, T. W. Smith, and C. R. Boyle. 1998. Broiler breeder age and dietary fat influence the yolk fatty acid profiles of fresh eggs and newly hatched chicks. Poult. Sci. 77:47–53.

38. Katanbaf, M. N., E. A. Dunnington, and P. B. Siegel. 1988. Allomorphic relationships from hatching to 56 days in parental lines and $F_1$ crosses of chickens selected 27 generations for high or low body weight. Growth Dev. Aging 52:11–22.

39. Smith, M. W., M. A. Mitchell, and M. A. Peacock. 1990. Effects of genetic selection on growth rate and intestinal structure in the domestic fowl (*Gallus domesticus*). Comp. Biochem. Physiol. 97A:57–63.

40. Berry, W. D., and J. Brake. 1991. Research note: Induced molt increases eggshell quality and calbindin-D28k content of eggshell gland and duodenum of aging hens. Poult. Sci. 70:655–657.

41. Li, B. T., A. G. Van Kessel, W. R. Caine, S. X. Huand, and R. N. Kirkwood. 2001. Small intestinal morphology and bacterial populations in ileal digesta and feces of newly weaned pigs receiving a high dietary level of zinc oxide. Can. J. Anim. Sci. 81:511–516.

42. Christensen, V. L., and W. E. Donaldson. 1992. The importance of timely removal from the incubator of hatched poults from three commercial strains. Poult. Sci. 71:1823–1829.

43. Donaldson, W. E., V. L. Christensen, and K. K. Krueger. 1991. Effects of stressors on blood glucose and hepatic glycogen concentrations in turkey poults. Comp. Biochem. Physiol. 100A:945–947.

44. Donaldson, W. E., J. Clark, and V. L. Christensen. 1994. Protein, lipid and glycogen stores in newly-hatched turkey (*Meleagris gallopavo*) poults as affected by post-hatch stressors and holding time. Comp. Biochem. Physiol. 107A:559–562.

45. Applegate, T. J., and M. S. Lilburn. 1999. Effect of turkey (Meleagris gallopavo) breeder hen age and egg size on poult development. 1. Intestinal growth and glucose tolerance of the turkey poult. Comp. Biochem. Physiol. B 124:371–380.

46. Applegate, T. J., E. Ladwig, L. Weissert, and M. S. Lilburn. 1999. Effect of hen age on intestinal development and glucose tolerance of the Pekin duckling. Poult. Sci. 78:1485–1492.

47. Christensen, V. L., J. L. Grimes, M. J. Wineland, and L. G. Bagley. 2001. Effects of turkey breeder hen age, strain, and length of the incubation period on survival of embryos and hatchlings. J. Appl. Poult. Res. 10:5–15.